Chapter 12. Mobile Robots

The Quest for Artificial Intelligence, Nilsson, N. J., 2009.

Lecture Notes on Artificial Intelligence, Spring 2012

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Contents

Overview of Chapter 12

- Up to this time, very little work had been done on mobile robots even though they figured prominently in science function.
- Beginning in the mid-1960s, several groups began working on mobile robots.
  - AI Labs at SRI and Stanford
  - The mobile robot project for the invention and integration of several important AI technologies
    - The SRI Robot, Shakey
    - The Stanford Cart

Chapter 12. Mobile Robots

12.1 Shakey, the SRI Robot

Shakey, the SRI Robot

- The SRI robot, "Shakey"
  - SRI's automaton project
  - Shakey had an on-board television camera for capturing images of its environment, a laser range finder for sensing its distance from walls and other objects, and cat-whisker-like bump detectors.

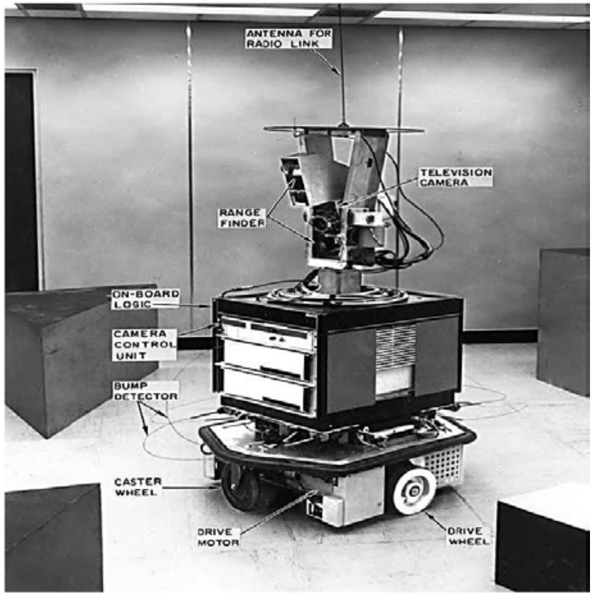

Figure 12.3: Shakey as it existed in 1968

Figure 12.4: C. A. Rosen with Shakey

12.1.1 A*: A New Heuristic Search Method (1/2)

- How to plan a sequence of “way points” that Shakey could use in navigating from place to place
  - Shakey kept information about the location of obstacles and its own position in a “grid model”, such as the one shown in Fig. 12.5.

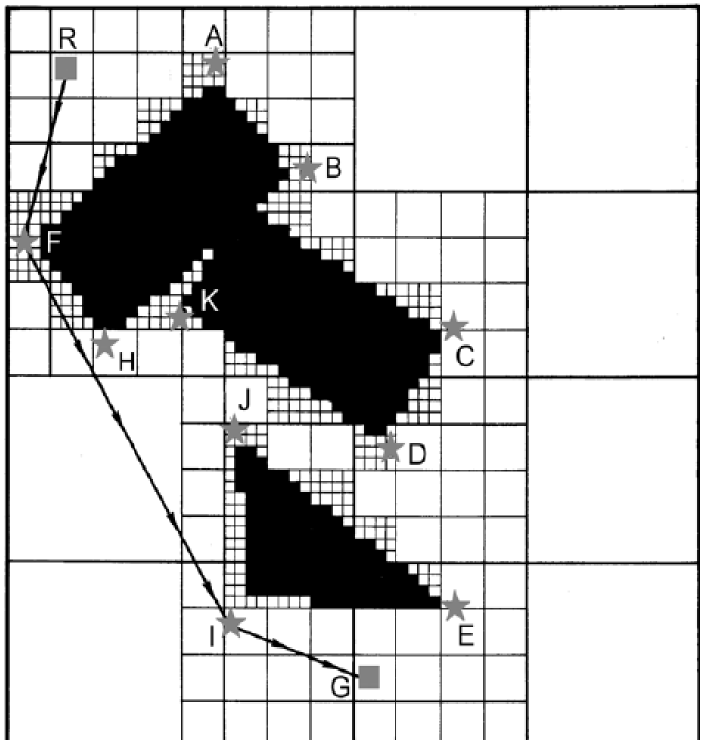

Figure 12.5: A navigation problem for Shakey

- For example, the navigation problem in which Shakey is at position R and needs to travel to G
  - The map shows the positions of three objects that must be avoided.
    - It is not difficult to compute the locations of some candidate way points near the corners of the objects (shaded stars).
  - Using techniques familiar in computer graphics, it also is not hard to compute which way points are reachable using an obstacle-free, straight-line path from R and G.

12.1.1 A*: A New Heuristic Search Method (2/2)

- Shakey's navigation problem is a search problem
  - How a search tree can be constructed and then searched for a shortest path from R to G.
  - The A* algorithm was embedded in Shakey's programs for navigating within a room containing obstacles.
- A* algorithm
  - P. Hart, N. Nilsson and B. Raphael described the algorithm in 1968.
  - The “A” was for algorithm and the “*” denoted its special property of finding shortest paths.
  - A* is an algorithm that uses heuristic to guide search while ensuring that it will compute a path with minimum cost.
  - A* computes the function that has the lowest $f(n) = g(n) + h(n)$
    - $g(n)$: the cost of the path from the starting node to goal node (actual cost)
    - $h(n)$: the heuristic estimated cost from the starting node to the goal node (estimated cost)

12.1.2 Robust Action Execution

- Navigation programs occupied the middle level of the hierarchy of Shakey's programs and these were all designed to achieve certain goals.
  - These were quite robust in that they “kept trying” even in the face of unforeseen difficulties.
  - How to achieve the robustness?
    - Inspired both by TOTE units and by the idea of homeostasis
      - TOTE (Test - Operate - Test – Exit) unit is an iterative problem solving strategy based on feedback loops
      - Homeostatic systems take actions to return them to stability in the face of perceived environmental disturbances.
    - The “Markov tables” for intermediate-level programs having “keep-trying” property was developed by R. Duda and N. Nilsson.

12.1.3 STRIPS: A New Planning Method

- Like humans, Shakey is sometimes need to be able to assemble a plan of actions and then to execute the plan.
  - Information needed for planning was stored in what was called an “axiom model”.
    - This model contained logical statements in the language of the predicate calculus.
      - (ex.) location: AT(ROBOT, 7,5) / push Box1: PUSHABLE(BOX1)
    - The first attempt at constructing plans for Shakey used the QA3 deduction system and the situation calculus.
  - STRIPS (Stanford Research Institute Problem Solver) is an automated planner developed by R. Fikes and N. Nilsson in 1971.
    - if (preconditions) then (retract <deletions>) (assert <additions>)
    - STRIPS replaced QA3 Shakey's system for generating plans of action.

12.1.4 Learning and Executing Plans

- The **triangle table** tabulated the preconditions and effects of each action in the plan so that it could keep track of whether or not the plan was being executed properly.
  - Actions in the plans generated by STRIPS had specific values for their parameters.
  - After a plan was generated, generalized, and represented in the triangle table, Shakey's overall executive program, called “PLANEX” supervised its execution.
    - PLANEX, using the triangle table, could decide how to get Shakey back on the track toward the original goal.
    - PLANEX gave the same sort of \keep-trying" robustness to plan execution that the Markov tables gave to executing mid-level actions.

12.1.5 Shakey's Vision Routines (1/2)

- Shakey's environment consisted of the floors, walls doorways between the rooms, and large rectilinear objects.
  - Visual processing still presented challenging problems
  - Both region finding and line detection were used in various of the vision routines for the mid-level actions.
    - One of these routines, called "obloc", was used to refine the location of an object whose location was known only roughly.
    - Another vision routine, called "picloc", was used to update Shakey's position with respect to the landmark, a nearby 'landmark' such as the corner of a room.
    - A routine called "clearpath" was used to determine whether its path was clear.
- Vision played an important part in Shakey's overall performance.
  - So, many of the visual processing techniques developed during the Shakey project are still used today.

12.1.5 Shakey's Vision Routines (2/2)

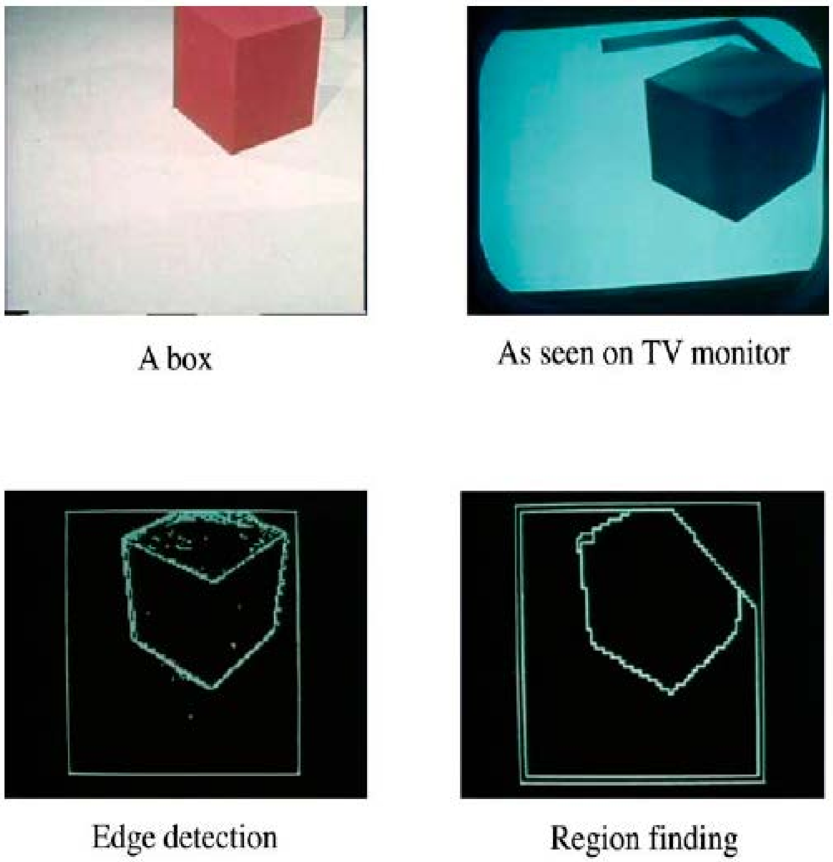

Figure 12.6: Using vision to locate an object. It show a box, how it appears as a TV image from Shakey's camera and two of the stages of obloc's processing.

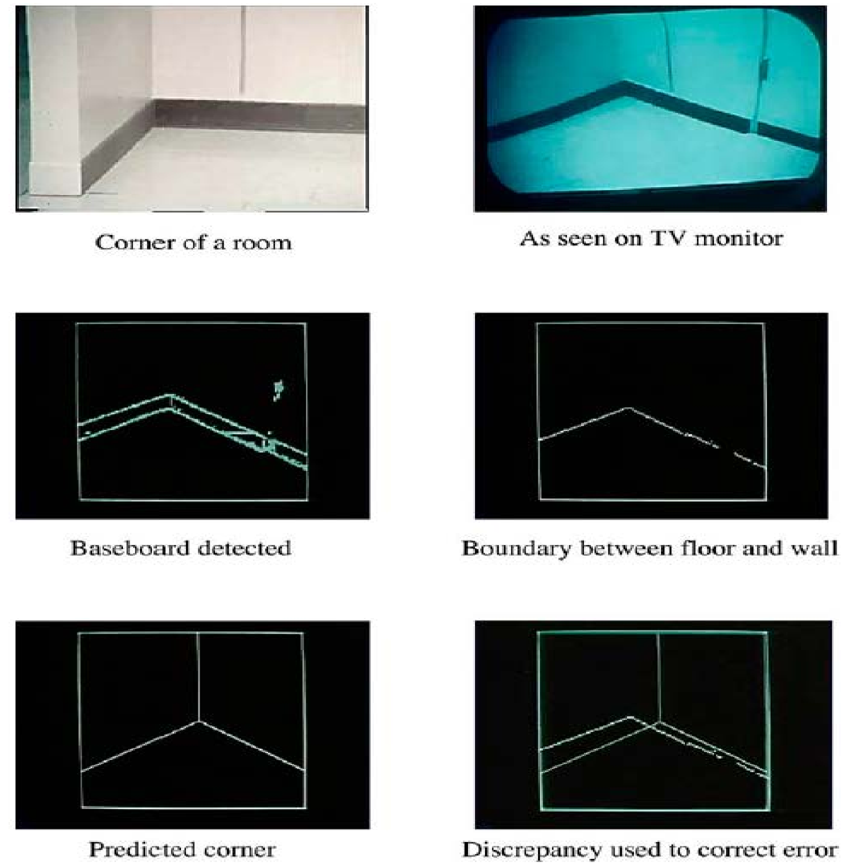

Figure 12.7: Using vision to update position The final picture shows the discrepancy between Shakey's predicted location of the corner and the actual location based on picloc.

12.1.6 Some Experiments with Shakey

- Give Shakey tasks stated in English.
  - L. Coles developed a parser and semantic analysis system that translated simple English commands into logical statements for STRIPS, called ENGROB.
    - For example, the task of box pushing just mentioned was posed for Shakey in English as follows:
      - Use BOX2 to block door DPDPCLK from room RCLK.
    - And ENGROB translated this English command:
      - BLOCKED(DPDPCLK, RCLK, BOX2)
- “push-the-box-off-the-platform” task
  - This task was given to Shakey in English as :Push the box that is on the platform onto the floor”
  - This task was Coles's way of showing that Shakey could solve problems requiring indirect reasoning

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12.2 The Stanford Cart

The Stanford Cart

- The "Stanford Cart" and SRI's "Shakey" were the first mobile robots controlled by computers (room-sized, radio linked).
  - The Stanford Cart was originally constructed by J. Adams to support his research on the problem of controlling a remote vehicle using video information.
  - P. W. Braisted devised a scheme to improve the controllability of the vehicle by adding a computer functioned as a predictor.

Figure 12.8: The Stanford cart

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Appendix

SRI's Automaton Project

- In 1963, C. Rosen (the leader of neural-network research at SRI) proposed the development of a mobile "**automaton**" that would combine the pattern-recognition and memory capabilities of neural networks with higher level AI programs.
  - In 1964, the proposal culminated in a "work statement" issued.
  - In 1966, the project was administered for ARPA by the RADC.
  - The "knitting together" of several disparate AI technologies was one of the primary challenges and one of the major contributions of SRI's automaton project.

A RESEARCH AND DEVELOPMENT PROGRAM IN APPLICATIONS OF INTELLIGENT

AUTOMATA TO RECONNAISSANCE

Goals

The long-range goal of this program will be to develop automatons capable of gathering processing and transmitting information in a hostile environment. The time period involved is 1970-1980.

The first short-range goal of the program will be to design and develop a mobile automaton to accomplish non-trivial missions in a real environment. External control will be exercised over the automaton from a computer. The automaton will have at least visual and tactile sensor capability.

The second short-range goal will be to design and develop a mobile automaton to accomplish non-trivial missions in a real environment in a self-contained mode, e.g., with little or no external control.

. . . .

Such a long-range goal attained by stepping through a number of intermediary ones is believed essential to knit together as many of the constituent subject areas of "artificial intelligence" as possible. It has been so stated as to require the successful application of many techniques with all the attendant problems of interaction and feed-back. It is difficult of realization but by the same token it will provide solutions to existing pressing military problems.

Figure 12.2: Excerpt from the typescript of the automaton work statement